Application

for

United States Patent

To all whom it may concern:

Be it known that, Jeff Jelinek

has invented certain new and useful improvements in

EXHAUST RECIRCULATING METHOD AND APPARATUS FOR A HYDROCARBON FIRED BURNER

of which the following is a description:

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EXHAUST RECIRCULATING METHOD AND APPARATUS FOR A HYDROCARBON FIRED BURNER

FIELD OF THE INVENTION

[0001] The present invention relates generally to a method and apparatus for hydrocarbon fired burners. More particularly, the present invention relates to a method an apparatus for reducing NO_x emissions from a hydrocarbon fired burner by recirculating some exhaust gases back into the burner.

BACKGROUND OF THE INVENTION

[0002] NO_x is a generic term applied to the oxides of nitrogen produced during the atmospherically oxidized combustion of hydrocarbon fuels. Most commonly these oxides are NO and NO_2. In recent years the reduction of NO_x emissions in combustion appliances has come under public scrutiny in all parts of the world. This comes largely due to the negative environmental effects such as acid rain in which NO_x is a contributor.

[0003] Many hydrocarbon fuels are burned using air. The elemental equation governing the stoichiometric combustion of most hydrocarbons with atmospheric air is

$$C_xH_y + (x + \frac{y}{4})(O_2 + 3.76N_2) \rightarrow xCO_2 + \frac{y}{2}H_2O + (x + \frac{y}{4}) \bullet 3.76N_2 + \text{energy}$$

[0004] The energy produced in this reaction is a direct contributor to the temperature, or flame temperature, T_f, of the reaction (See Fig. 4). FIG. 4 is a general figure illustrating the trend of the concentration of NO_x with respect to the flame temperature. In most stoichiometric combustion systems, $T_{f,stoich}$ is so high

that the normally inert and stable N_2 is broken down and reacts with any available O or O_2 that is in the combustion zone thereby producing NO_x. Generally, NO_x emissions are insignificant when below a critical flame temperature, $T_{f,critical}$, and rise dramatically when T_f is greater than $T_{f,critical}$.

[0005] As shown from FIG. 4, NO_x increases considerably as $T_{f,critical}$ is exceeded. Also, $T_{f,critical}$ is generally less than $T_{f,stoich}$. Thus, under near perfect stoichiometric combustion conditions, NO_x can be at an undesirably high level. From the graph, it can be concluded that if T_f is only slightly less than $T_{f,critical}$, NO_x can be greatly reduced. One way to reduce the T_f is to increase the amount of excess air, (%EA), delivered to the combustion process. (When %EA = 0, air to fuel ratio is stoichiometric, so as %EA increases, there is a greater than stoichiometric concentration of atmospheric air present.)

[0006] By increasing %EA, T_f can be reduced, but due to the higher concentrations of O_2 and N_2, the NO_x also increases. However, because, most all practical combustion processes require %EA greater than 0 to insure that non-desirable products such as CO are not formed, a trade off exists between the NO_x, T_f, and %EA.

[0007] Accordingly, it is desirable to be able to reduce T_f without increasing %EA to an undesirably high level and thus provide a burner that can emit reduced NO_x emissions.

SUMMARY OF THE INVENTION

[0008] The foregoing need to reduce NO_x with out increasing %EA to an undesirable level, are met, to a great extent, by the present invention, wherein in one aspect an apparatus is provided where in some embodiments of the invention, EGR contributes to the reduction of NO_x emissions during the combustion

process. Reduction of NO_x emissions can achieve reduction in NO_x because of the lowering of T_f and the low O_2 and N_2 in the recirculated gas.

[0009] In accordance with one embodiment of the present invention, a system for a hydrocarbon fired burner is provided. The system includes an exhaust conduit in fluid communication with the burner, a recirculation conduit configured to provide, at least at times, fluid communication between the exhaust conduit and a burner inlet, an adjustable valve configured to selectively permit the recirculation conduit to provide fluid communication between the exhaust conduit and the burner inlet, a NO_x sensor located in the exhaust conduit, a system controller operably connected to the NO_x sensor and configured to monitor an amount of NO_x emissions in the exhaust conduit, the system controller also operably connected to the valve to adjust the valve.

[0010] In accordance with another embodiment of the present invention, a system for a hydrocarbon fired burner is provided. The system includes means for exhausting combustion gases in fluid communication with the burner, means for recirculating combustion gases from the exhausting means with the burner, means for selectively permitting the recirculation means to provide fluid communication between the exhausting means and the burner, means for sensing NO_x located in the exhausting means, means for controlling the system operably connected to the NO_x sensing means and configured to monitor an amount of NO_x emissions in the exhausting means, the controlling means also operably connected to control the permitting means.

[0011] In accordance with yet another embodiment of the present invention, a method of reducing NO_x emissions in an appliance having a burner is provided. The method includes detecting NO_x emissions in exhaust associated with the burner, determining if a recirculation valve should be one of open,

closed, and remain the same according to the predetermined criteria, and one of adjusting the valve and leaving the valve in a current position in accordance with the result of the determining step.

[0012] There has thus been outlined, rather broadly, certain embodiments of the invention in order that the detailed description thereof herein may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional embodiments of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0013] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of embodiments in addition to those described and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

[0014] As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a schematic diagram of a preferred embodiment of a system in accordance with the present invention.

[0016] FIG. 2 is a schematic diagram of an embodiment of a system in accordance with the present invention.

[0017] FIG. 3 is a flowchart of a method in accordance with the present invention.

[0018] FIG. 4 is a graph of NO_x emissions vs. flame temperature illustrating a relationship between flame temperature and NO_x emissions.

DETAILED DESCRIPTION

[0019] The invention will now be described with reference to the drawing figures, in which like reference numerals refer to like parts throughout. An embodiment in accordance with the present invention provides a system and method for reducing NO_x emissions in burners that burn hydrocarbon fuel such as fuel oil, natural gas, propane or other similar fuel.

[0020] Some embodiments of the invention may be directed to household appliances such as a water heater, furnace, or other device having a burner which burns hydrocarbon fuel. Other embodiments of the invention may be directed to commercial or industrial type burners.

[0021] Some embodiments of the invention will have an inlet for providing fresh air to be mixed with the fuel to be burned in the burner. Once the fuel and air have been burned, the resultant gases are exited from the burner through an exhaust system. The exhaust system is configured to allow recirculation of exhaust gases back into the fresh air inlet of the burner under certain conditions. The recirculation of exhaust gases mixing with the fresh air

and then inlet into the burner can, under certain circumstances, reduce the NO_x emissions of the burner. While the description herein discloses household appliances as an example of a use of the invention, the invention is not limited to household appliances, but rather the invention may be directed to any suitable combustion device.

[0022] One method of reducing T_f is through exhaust gas recirculation (EGR). EGR is a method in which a portion of the gases that have already completed the combustion process are brought back into the combustion zone in attempts to lower the T_f to a level below $T_{f,critical}$ thereby lowering the NO_x. There are two characteristics of the exhaust gas that help lower the NO_x. The first is that the temperature of the recirculated exhaust gas is much lower (<5x) than T_f. Hence, as the cooler exhaust stream is mixed with primary combustion zone gases, the overall mean temperature of the combustion zone is reduced. The second quality of the exhaust gas that is critical in the role of NO_x reduction is the chemical makeup of the gas. After completing the combustion process, the exhaust gases have a relatively low volumetric concentration of excess oxygen and nitrogen. Since, O_2 and N_2 are quite low, there is a very low propensity for the additional NO_x production.

[0023] An embodiment of the present inventive apparatus is illustrated in a schematic diagram in FIG. 1, which shows the system 10 including an appliance 12. The appliance 12 may be a hot water heater or a furnace or any other appliance having a burner that burns hydrocarbon fuels. Fresh air 14 from the outside is brought into the appliance 12 through an inlet 16. The appliance 12 has a burner 18 in which combustion occurs. After the combustion has occurred within the burner 18, the exhaust gases 20 are outlet from the burner 18 and/or appliance 12 via an outlet 22. The exhaust gases 20 may be vented to the outside

via a chimney flu or other suitable venting type system. A portion of the exhaust gases 20 are diverted through a recirculation circuit 24 according to the needs of the system 10.

[0024] The recirculation circuit 24 includes a valve 26 that is operably connected via connector 28 to an NO_x sensor 30. The valve 26 can be a solenoid valve. Other embodiments of the invention may include a proportion valve. The valve may have a digital processor and on board system memory. Embodiments having a digital processor and system memory will be discussed in more detail below.

[0025] The NO_x sensor 30 senses the NO_x emissions in the exhaust gases 20. Based on the amount of NO_x emissions detected in the exhaust gases 20, the valve 26 will open, close or remain in its current setting according to a predetermined schedule. The predetermined schedule is set according to the needs and requirements of the individual system.

[0026] The exhaust gases 20 that are permitted to flow through the valve 26 are referred to in this document as recirculation gas 32. The recirculation gas 32 is mixed with the fresh air 14 from the outside to comprise appliance inletting gases 36. The inletting gases 36 are inlet to the appliance 12 and/or burner 18 via an inlet 16.

[0027] FIG. 2 is a schematic diagram of an embodiment in accordance with the present invention having additional features than those described in FIG. 1. FIG. 2 shows an appliance 12 having an exhaust pipe 38 containing exhaust gases 20. While the term "pipe" is used throughout this document, it is understood that the invention is not limited to using only pipes. Systems in accordance with the present invention may use other flow containing means or conduits suitable to accomplish the invention. A NO_x sensor 30 is inserted into

the stream of the exhaust gases 20 and is operably connected to a system controller 40 via a connector 42. In other embodiments in accordance with the invention, other types of connections between the sensor 30 and the system controller may be achieved. For example, there may be a wireless connection or any other suitable type connection may be used.

[0028] The system controller 40 may include a microprocessor or any other programmable or non-programmable type controller. Where the valve 26 has a digital processor, that processor may be part of the system controller 40. The predetermined schedule can be programmed into the system controller 40. Some embodiments of the invention may include a system controller 40 that has the predetermined schedule embedded into the hardware of the system controller 40. Other embodiments of the invention may include the system controller 40 to be software programmed onto a processor or computer. According to some embodiments of the invention, the predetermined schedule may be modified by inputting modifications according to specific needs or changing conditions of a specific system.

[0029] The recirculation circuit 24 includes a recirculation pipe 44 connected to the exhaust pipe 38. The recirculation circuit 24 permits exhaust gases 20 to flow selectively through the recirculation pipe 44 as permitted by the valve 26. The valve 26 is operably connected to the system controller 40 via a connection 46 as shown in FIG. 2. In other embodiments in accordance with the present invention the valve 26 can be in communication with system controller 40 via wireless connection or any other suitable means.

[0030] An inlet pipe 48 inlets fresh air for combustion into the burner 18 and/or appliance 12. The recirculation pipe 44 is connected to the inlet pipe 48 and permits recirculation gas 32 to mix with fresh inlet air 14. The mixing of

inlet air 14 and recirculation gas 32 results in mixed intake gas 36. The mixed intake gas 36 is then inlet to the burner 18 in the appliance 12.

[0031] The NO_x emissions detected by the NO_x sensor 30 are imputed into the system controller 40. Optionally, the system controller 40 may record the NO_x emissions into a database 50 which may be connected to the system controller by connection 52 through any suitable means. In embodiments of the invention using a valve 16 that has an on board system memory, that memory may store the database 50.

[0032] The system controller operates the valve 16 to open, close or remain in a current position according to a predetermined schedule to achieve the desired amount of NO_x emissions in the exhaust gases 20. It is understood that some embodiments of the present invention use a valve 16 with only an open and closed position. Other embodiments use a valve 16 with variable positions. The term open refers to moving to at least more open position and close refers to moving to at least a more closed position.

[0033] In cases when the exhaust gases contain an unacceptable level of NO_x emissions, the system controller 40 in some embodiments of the invention will communicate to a burner controller 54 via a connection 56 or any other suitable communication means. The burner controller 54 will control combustion within the burner 18 and may reduce or increase the amount of fuel inlet to the burner 18, it may increase or decrease the amount of inlet gases 36 applied to the burner 18, or it may cause the burner 18 to shut down. The system controller 40 will control the burner controller 54 according to the detected NO_x emissions and the predetermined schedule. In other embodiments of the invention the system controller 40 will directly control the burner 18 directly.

[0034] Some embodiments in accordance with the invention may include an alarm system connected to the system controller 40 permitting the system controller 40 to activate an alarm system 58 if NO_x emissions in the exhaust gases 20 are at an unacceptable level. The alarm system 58 may be connected to the system controller 40 by a connector 60 by any suitable connection means. In other embodiments of the invention, the system controller 40 may notify maintenance personnel if NO_x emissions achieve an unacceptable level. Embodiments of the invention, where maintenance personnel are notified when NO_x emissions are at an unacceptable level, may be particularly suitable for use in a commercial setting.

[0035] FIG. 3 is a flowchart illustrating a method in accordance with the invention. In the step 62, NO_x emissions are detected in flue and/or exhaust gases.

[0036] The next step 64, is optional. In step 64, the exhaust gas emissions results are recorded in the database.

[0037] In the next step 66, which is also an optional step, the system determines whether the NO_x emissions are at acceptable levels. If they are not at an acceptable level, the system may shut the burner (step 68), sound the alarm (step 70), or notify maintenance personnel (step 72). If the NO_x emissions are at an unacceptable level, the system proceeds to the next step 74.

[0038] In step 74, the system determines if the valve should be open, closed or remain at the current setting.

[0039] In step 76, the valve is adjusted according to the determination made in step 74, then the process is repeated in step 78.

[0040] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to

cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.